Farmers' direct-sowing practices in rainfed lowland rice in southern Thailand: improving a traditional system

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For many decades, dry seeding was the dominant farmers' practice for establishing rainfed lowland rice (RLR) in the drought- and submergence-prone areas bordering the Songkhla lagoon along the eastern coast of southern Thailand. Because of the highly constraining soil-water complex, RLR growers have been combining an array of dry-seeding and transplanting practices adapted to varying soil and climatic conditions to be able to grow rice in their fields every year, although with a relatively low but rather stable crop productivity.

During the past decades, RLR dry-seeding techniques dominated the three main types of household-based farming systems, while paddy fields most infested by weeds, particularly wild rice, were transplanted. Land preparation and crop establishment on heavy-textured soils, water depth control, and weed infestation, especially by wild rice, were found to be major interrelated problems that can be addressed by strategic and applied research to stabilize yields and increase labor productivity of local dry-seeded rice systems.

Labor productivity in dry-seeded paddies is often very low because of the tedious and highly time-consuming hand-weeding and thinning-transplanting practice. At least 50 d ha^{-1} are needed to achieve an RLR yield of more than 2.2 t ha^{-1} and 150 d ha^{-1} in wild rice-infested fields for effective control by using the integrated approach designed over time by farmers. Agronomic and economic results of on-farm experiments on land preparation and row seeding demonstrate the potential of this technique in high weed-infestation situations.

Recently, a limited crop diversification scheme based on integrated systems of small-scale crop-fish rearing led to an improvement in the capture of water and supplementary irrigation. During the 1987-96 decade of high economic growth, the scarcity of farm labor increased because off-farm employment opportunities were more attractive and readily available. As a consequence, in associa-

tion with adopting new early maturing cultivars and combined with mechanizing the RLR harvest, an important increase in wet-seeded rice has been observed since 1996.

For many decades, dry seeding was the dominant farmers' practice for establishing rainfed lowland rice in the drought- and submergence-prone areas bordering the Songkhla lagoon along the eastern coast of southern Thailand. Because of the highly constraining soil-water complex, rainfed lowland rice (RLR) growers developed dry-seeding practices adapted to varying soil and climatic conditions to grow rice in their fields every year, although with a relatively low but rather stable crop productivity (Trébuil 1987, 1988, Pandey and Velasco, this volume). On-farm diagnostic surveys carried out in the area in the 1980s found that land preparation of heavy-textured soils, RLR crop establishment techniques, water depth control, and weed infestation, especially by wild rice, were major and interrelated limiting factors in RLR production (Crozat and Chitapong 1988, Trébuil et al 1984). This article summarizes the main findings of a series of on-farm research studies carried out in Sathing Phra District of Songkhla Province. It has the following objectives:

1. To analyze farmers' practices and strategies regarding the selection of crop establishment techniques in RLR,
2. To quantify the effects of these techniques and other related cultivation practices on RLR yields and labor productivity,
3. To assess the potential of row seeding in medium RLR paddies,
4. To understand recent local patterns of change in RLR crop establishment methods, and
5. To identify key strategic and applied research issues for improving local RLR production.

Materials and methods

An in-depth and comprehensive on-farm diagnostic analysis of the Sathing Phra agrarian system was carried out during the 1982-83 wet season (WS) (Trébuil 1984, 1987). Following the on-farm testing of innovations for the two main economic activities in the area—RLR production during the wet season (July-February) and palm sugar production during the dry and prehumid seasons (January-June)—the evaluation of their impact and a rapid appraisal of changes in the functioning of the farming systems were implemented during the 1987-88 WS (Trébuil 1988).

On-farm experiments on land preparation and row seeding carried out in 1987-88 compared dry-seeded rice (DSR) plots established by manual broadcasting (BC, the most frequently used farmers' practice) and row seeding (RS) on six farms. The IRRI-designed two-row seeder was pulled by a hand tractor equipped with caged wheels. Observations were gathered on sowing densities, RLR plant densities at emergence and at harvest, degree of weed infestation, weeding practices, monitoring of floodwater level, and RLR yield. All variable and fixed costs for both crop establishment techniques were recorded to carry out a partial budgeting analysis (Harrington et al 1986). This type of economic analysis was conducted to help identify RLR crop situations in which the row seeder could significantly help farmers achieve their economic objectives. Costs that vary between RS and BC treatments were first estimated, then benefits and marginal rates of return to capital were calculated. The effects of the RS technique on labor productivity (value added per unit of labor) were also assessed.

A rapid appraisal survey was carried out in January 2000 to update information from previous diagnostic studies in the same three villages located along an east-west transect in the most diverse southern part of Sathing Phra District. This time, the survey emphasized the identification of recent changes in RLR crop establishment practices and their interpretation through the analysis of transformations of biophysical and socioeconomic conditions of agricultural production in this area. Runs of transects crossing the main rice-based agroecological units of the landscape and farmers' interviews were used to collect information on these topics.

Agroecological characterization of the study area

Located on a narrow peninsula between the Gulf of Thailand and the Songkhla lagoon, the RLR growing area of densely populated Sathing Phra District, with more than 400 inhabitants km^{-2}, is a drought- (at vegetative stage from July to September) and submergence-prone (during the peak of the rainy season in November-December) ecosystem with a very constraining soil-water complex. Apart from the narrow sand bars to the east on which limited rice production in upper paddies is done (mainly dry-seeded nurseries, which are later only thinned or completely pulled and transplanted, accounting for some 3% of the RLR area), RLR is mainly grown in medium paddies on very heavy soils with slow drainage, and a clay content of more than 40%, where the crop is closely associated with sugar palms. Medium paddies represent some 85% of the total RLR area and lower paddies on very heavy soils with a clay content of more than 60% located in low-lying, submergence-prone areas, and without sugar palms associated with rice, make up the remaining 12% of the local RLR planted area.

The onset of the wet season in this area is very unpredictable and, in some years, the prehumid season, during which rainfall is less than potential evapotranspiration (PET) but more than half of PET, can last from April to September (Crozat et al 1985). As most of the total annual rainfall is concentrated over the last three months of the year, farmers have developed many climatic risk avoidance strategies and practices to cope with such conditions, which allow them to establish RLR and some deepwater rice (in agroecological unit 3) every year in all their fields.

Main types of rice-based farming systems

Based on farmers' socioeconomic strategies and availability of land, labor, and capital resources, three main types of farming systems can be distinguished (Trébuil 1988):

- Type I: very small farms (0.3 to 0.4 ha per unit of labor) where, year-round, most of the family workforce is employed in nonrice economic activities to maximize family labor income, such as palm sugar production, but also for more and more

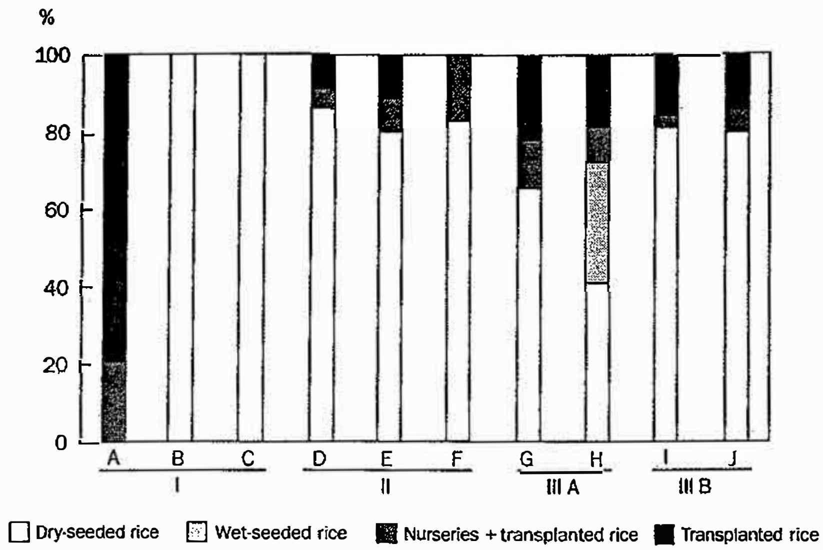

Fig. 1. Percentage of the rainfed lowland rice area per crop establishment technique and by type of farmer (I, II, IIIA, IIIB) on 10 farms (A to J) in Sathing Phra, southern Thailand.

wage-earning activities, especially in Songkhla-area canning factories for sea products. For this reason, farmers' paddy fields are either transplanted in the case of very small farms or totally dry seeded (Fig. 1). Rice production here is exclusively for family consumption. Depending on the village, 50–60% of the total number of farms in the area belong to this type. Because of the limited role of RLR on these tiny farm holdings, improving their production is not a priority to households.

- Type II: medium-sized farms (0.5 to 0.8 ha per unit of labor) with few nonrice activities during the wet season. Labor productivity in RLR is very low because of intensive hand weeding, thinning, and seedling redistribution implemented in dry-season (DS) plots by family labor (up to 200 person-d ha^{-1}), except in remote fields. Only 16% of those remote fields were hand-weeded during the 1982-83 WS versus 86% for fields located a short distance away from the village. Cattle rearing, with weeds from RLR fields as a major source of forage during the wet season, is another common activity on these farms that market up to 50% of their rice production. Depending on the village, 25–40% of the farms belong to this type of farming system.
- Type III: larger, more productive farms where intensive rice production techniques have been introduced, such as wet seeding or transplanting of shorter duration recommended varieties that were grown on 50% of their paddy fields in the early 1980s to increase the net benefit per land unit (subtype IIIA). A more labor-extensive rice production system is adopted on the largest holdings with

more than 0.8 ha per unit of labor and up to 8 ha per unit of labor (subtype IIIB). Because maximizing productivity of scarce labor resources is the farmers' key management criterion here, few days are spent hand weeding rice fields; 10–15% of farms belong to this type and farmers sell more than half of their rice produce on the market.

Each farm has access to several RLR fields distributed across the three different main agroecological units, where different RLR production techniques are implemented to suit field hydrological conditions to limit the risk of crop failure, and to stagger labor requirements during land preparation, crop establishment, weeding-thinning-seedling redistribution in DSR fields, and harvest. Because of differing management strategies and the relative importance of RLR in the main farming systems, efforts to improve RLR cropping systems focus on farm types II and III.

Results and discussion

During the 1980s, direct dry seeding was the dominant type of RLR crop establishment technique for all three types of farming systems. This could be explained by the general absence of water control that limited the duration of optimal field conditions for transplanting. As a consequence, during the 1982-83 WS, only 20% of the area planted to RLR was transplanted, generally with early maturing recommended varieties, and mainly on type III farms employing a significant amount of hired labor. In that period, 90% of the fields planted to the most popular local photoperiod-sensitive RLR cultivar, called "Sali," were dry-seeded, especially on farm types I and II.

Diversity of crop establishment practices traditionally dominated by DSR

Based on results from the extensive RLR field monitoring survey carried out in the early 1980s, Table 1 summarizes the important diversity of sets of cultivation practices selected by farmers. Such a wide variability in farmers' practices is due to unpredictable climatic conditions and lack of good water control at the field level. Depending on the type of equipment used (tractor, hand-tractor, oxen), the number of passes (from one to three), and type of sowing technique adopted (broadcast seeds plowed in when sowing during a rainy period, or not covered in the case of predominantly drier weather conditions), as many as seven different major patterns of cultivation practice were used to establish DSR on farms belonging to types II and III. When all successive techniques (different types of nurseries, farm equipment, etc.) involved in crop establishment were taken into account, 21 patterns were found.

In Sathing Phra District, farmers were using 64 different RLR varieties. These varieties displayed very different crop cycle durations (from 4 to more than 7 months), but a tendency toward selecting more early maturing cultivars was observed on most of the farms during the 1980s (Trébuil 1987) and again since 1996. In broadcasting, seeding rate was higher where seeds were covered by a second pass of the plow or by harrowing (51 kg ha^{-1}) than where seeds were not covered (39 kg ha^{-1}). This latter

Table 1. Characterization of the diversity of cultivation practices in RLR fields of Sathing Phra, southern Thailand. Data collected from 158 paddy fields belonging to 10 farmers, 1982-83 wet season.

Type of RLR subecosystem	RLR cultivars (no.)	Crop establishment techniques[a] (period)	% area per RLR subecosystem	Hand weeding time (min.-max., d ha^{-1})	Mineral fertilization (min.-max., kg N ha^{-1})
Upper paddies	3	1	24		
		3	64	0–80	0–32
		4	12		
		(Sep–Oct)			
Medium paddies	19	1	73		
		2	4	0–190	0–66
		3	19		
		4	4		
		(July–Oct)			
Lower paddies	7	1	95		
		3	5	0–125	16–80
		(July–Aug)			

[a]Crop establishment techniques: 1 = dry-seeded rice (DSR), 2 = wet-seeded rice, 3 = transplanted rice (TPR), 4 = partially pulled nursery. Partially pulled nurseries are dry-seeded nurseries in which farmers pull only the number of seedlings they need for transplanting in TPR fields or to fill gaps in DSR fields. The remaining seedlings are left to complete their vegetative cycle until harvest.

practice is followed by farmers who anticipate a predominantly dry climate during the following days. This is because, for plowed-in BC seeds, the emergence rate is lower because of losses in seeds located deeply between clods.

Figure 1 shows the extent of the different kinds of RLR crop establishment techniques according to the type of household-based production system. The figure also shows that, apart from TPR fields, a significant share of the RLR seedlings produced in nurseries are used to fill gaps in DSR fields as well, especially in farm type II and IIIA paddies. Apart from the tiniest rice holdings belonging to type I that are not self-sufficient, DSR was the preferred technique used by farmers in 75% of the RLR planted area. The early maturing recommended cultivars are planted in September, after the local more drought-tolerant ones have been planted. This practice decreases the risk of drought during the vegetative phase of the crop cycle (Table 2).

Although only a few type III farmers were introducing WSR in the early 1980s on 5% of the RLR area, the remaining paddy fields were transplanted in October-November. To stagger work on the farm, transplanting of early maturing recommended varieties is carried out during the period between establishing DSR fields and hand weeding–thinning–seedling redistribution in those dry-seeded plots. Usually, transplanted rice (TPR) is found in fields most infested by weeds, especially wild rice, following several crop cycles of DSR. The farmers' practice of minimum land preparation (one pass with an oxen or disk plow) and early broadcasting of DSR usually leads to heavy weed infestations in years with a late onset of the rainy season. Highly time-consuming hand weeding, usually combined with thinning-replanting, is generally needed to homogenize the plant population in DSR. This can only be done during a limited period

Table 2. Risk of drought during the early vegetative phase in dry-seeded paddies of the two main rainfed lowland rice (RLR) subecosystems of Sathing Phra, southern Thailand.

RLR subecosystem (amount of water available) and type of cultivar	RLR sowing date	Probability of drought stress[a] before tillering[b]
Medium paddies (300 mm)	11 Sep	0.52
Medium-maturing varieties	21 Sep	0.24
(150–160 d)	1 Oct	0.08
Lower paddies (550 mm)	11 Sep	0.64
Late-maturing varieties	21 Sep	0.52
(180–200 d)	1 Oct	0.24

[a]Soil moisture at less than field capacity during the first three 10-d periods after sowing. [b]Water balance calculated for 25 y from rainfall and potential evapotranspiration, with losses from percolation and capillarity estimated at 1 mm d^{-1} and soil moisture content at sowing equal to wilting point.
Source: adapted from Crozat et al (1985).

determined by soil-water conditions. It can begin on clayey soils as soon as field capacity is reached but it has to be stopped when fields are flooded. For this reason, hand weeding tends to start late, generally 45 to 60 d after sowing, and after wet seeding and transplanting work are completed. Lower RLR paddies are the first to be flooded and hand-weeded, but every year only part of the fields can be completely hand-weeded as the number of suitable days and amount of labor for weeding-thinning-seedling redistribution are limited, even on type II farms. Consequently, the quality of land preparation and initial RLR crop establishment, by limiting the requirement for hand weeding-thinning-seedling redistribution ("plot repair" work in farmers' words), can play an important role in the performance of RLR at the field and farm levels.

Figure 2 shows the amount of weeding time spent by farmers in their RLR paddies according to each of the three main types of farming systems. Type III holdings, with less labor available per hectare, tend to spend less time in hand weeding fields than type II farms, with less alternative employment opportunities during the wet season. Table 3 also shows the distribution of time spent in hand weeding-thinning-seedling redistribution in RLR fields. Data show that, depending on the year, one-third to one-half of DSR fields required more than 100 person-d ha^{-1} for weeding. When no hand weeding-thinning-seedling redistribution at all can be done, such as in remote rice fields, yield losses varied from 25% to 50% compared with weeded plots, depending on the type and intensity of the weed competition (Trébuil 1987). Among local DSR medium paddies, in terms of plant density, all transitional stages between a dry-seeded field and a dry-seeded nursery (established following the same land preparation and sowing techniques, with only a much higher seeding rate) can be found depending on the number of seedlings being pulled for use in other fields after the start of the rainy season. Mineral fertilization of DSR partly depends on the hand weeding-thinning-seedling redistribution practice. If weeding can be completed on time, a second fertilizer application is usually made, following the first one at sowing or, more often, at the tillering stage. But the second one is cancelled if weed control cannot be done properly, leading to a drop in RLR productivity.

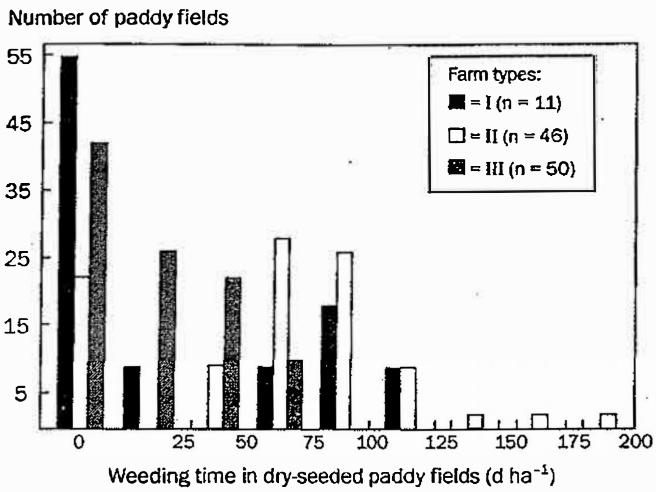

Fig. 2. Hand-weeding time in dry-seeded paddy fields for the three main types of farming systems (I, II, III) in Sathing Phra, southern Thailand, 1982-83 wet season.

Table 3. Distribution of working time (% of fields) spent in hand weeding–thinning–seedling redistribution in direct-sown rainfed lowland rice fields of Sathing Phra, southern Thailand.

Crop year[a]	Person-d ha^{-1} 0–19	20–39	40–79	80–99	100–149	>150
1982-83 WS	28	8	9	8	22	25
1984-85 WS	5	10	40	13	13	19

[a]Data came from 88 fields during 1982-83 wet season (WS) and 22 fields during 1984-85 WS.

Variability of RLR crop productivity

Maximum yields achieved by farmers for each of the three main types of RLR subecosystems were 1.9, 2.5, and 4.2 t ha^{-1} for upper/sandy, lower/very clayey and submergence-prone, and medium/clayey paddies, respectively. In the 1982-83 WS, the average local RLR paddy yield was 1.8 t ha^{-1}. A minimum of 50 person-d ha^{-1} for hand weeding-thinning-seedling redistribution was needed to achieve a yield of 2.2 t ha^{-1} or more (Trébuil et al 1984). Table 4 shows that, if average yields for DSR and TPR were 1.7 and 2.2 t ha^{-1}, respectively, interfield variations in RLR yields were important in both cases. Diagnostic agronomic studies conducted to explain this variability in RLR yields in farmers' fields found that land preparation and poor crop establishment, water depth, weed competition, particularly by wild rice, and damage caused by rats and crabs in densely planted fields with early maturing cultivars were major factors limiting RLR productivity (Crozar and Chitapong 1988).

Table 4. Comparison of crop and labor productivity in rainfed lowland rice between the main crop establishment techniques in medium paddies of Sathing Phra, southern Thailand, 1982-83 wet season.

Crop establishment technique	Yield (t ha^{-1})			Person-d ha^{-1}			Kg paddy person-d^{-1}		
	Min.	Max.	Av	Min.	Max.	Av	Min.	Max.	Av
Dry-seeded rice	0.5	3.0	1.7	8	220	107	7	40	21
Wet-seeded rice	2.4	2.9	2.6	98	150	124	16	25	21
Transplanted rice	0.9	4.2	2.2	45	161	97	8	47	24

Labor productivity analysis

Depending on the type of farming system, the total amount of time spent in RLR fields varies. Type I farms invest from 62 to 94 person-d ha^{-1}, with women exclusively in charge of transplanting, thinning-seedling redistribution, and harvesting, while men give priority to off-farm employment. A similar amount of person-d ha^{-1} is observed on type III farms, but here the labor force works in many more fields and on a larger planted area. With few other employment opportunities during the rice crop cycle, type II farmers invest from 94 to 140 person-d ha^{-1} in their RLR fields. They aim to maximize the productivity of family labor through allocation among different blocks of paddy fields.

During the 1980s, the levels of gross labor productivity in rice for each of the three types of farming systems were 19–24, 13–15, and 20–30 kg paddy d^{-1} for types I, II, and III, respectively (Trébuil 1987). If only family labor is taken into consideration, these numbers change to 29–95, 13–16, and 26–88 kg paddy per d^{-1} for types I, II, and III, respectively, displaying a greater difference between household categories, while displaying similar between-field ranges of variation in performance. Table 4 shows that the average gross labor productivity was somewhat lower in DSR than in TPR, but this difference was not statistically significant. This was because of the large amount of time spent in hand weeding–thinning–seedling redistribution in DSR. This is also associated with a more frequent harvesting of RLR panicle by panicle, using the traditional digital blade called *kae* in broadcast DSR fields where maturity is more heterogeneous. From zero up to 100 person-d ha^{-1}, it was also found that each additional hand-weeding day increases RLR paddy yield by 72 kg ha^{-1}. This illustrates the important yield-depressing effect of weed competition in local DSR paddy fields.

Farmers' integrated approach to controlling wild rice

Following many decades of RLR cultivation with DSR as the main crop establishment technique, among the different types of weeds found in Sathing Phra paddies, wild rice is the most dreaded by farmers (Trébuil et al 1984). Up to more than 100 wild rice seedlings m^{-2} are observed in some fields a few weeks after sowing. Natural crosses by which the wild rice phenotype becomes closer to that of cultivated RLR varieties also make wild rice more and more difficult to control. Because no adapted chemical control method is available, farmers have adopted an integrated control approach, which is mainly based on a sequence of time-consuming cultivation practices.

Farmers assess the extent of wild rice infestation during the fallow period, at the very beginning of the rainy season, by looking for "red rice" grains on the ground. If infestation is high, TPR will be grown. Many times, sequential tillage operations are used to try to produce clean seedbeds. If, after emergence of DSR seedlings, wild rice infestation is high, the young crop is plowed under and the plot prepared again and wet-seeded or transplanted. RLR varieties with specific morphological characteristics (shape and color of leaf, pattern of spatial distribution of tillers, etc.) are chosen to provide a distinction between wild and cultivated rice to facilitate hand weeding. For the past 5 years, farmers also tended to grow more early maturing varieties, which are harvested before wild rice grains mature and shatter on the ground. In dry-seeded fields, farmers prepare relatively coarse seedbed structures with an average clod size of 10-cm diam. Cultivated RLR seedlings emerge faster between these clods whereas seedlings germinating on clods that tend to emerge later are all wild rice and are more easily identified and hand-weeded. Seeds for future cropping seasons are selected by harvesting panicles one by one using the traditional *kae*. When hand weeding has to be stopped when fields are permanently flooded, wild rice plants are cut by a sickle before they flower and are used to feed cattle in December and January. Later, as heading of wild rice usually occurs before that of local cultivars, wild rice panicles are cut by using the *kae* to limit further infestation.

Generally, not all of these practices can be carried out in infested fields during the same season and very often wild rice infestation is poorly controlled because of the lack of labor. Effective hand weeding in wild rice-infested DSR fields by using the earlier techniques mentioned required 150 person-d ha^{-1}. This also explains why, as labor availability is decreasing, farmers have recently increased the use of wet seeding to establish their crops and control wild rice better.

Potential of row seeding to improve crop establishment and weed control

During the 1987-88 wet season, a series of on-farm experiments on land preparation and row-seeding were carried out to improve weed control, emphasizing wild rice, and to increase labor productivity in RLR (Moreau et al 1988). An IRRI-designed two-row seeder pulled by a hand-tractor was tested to establish a homogeneous plant stand and to facilitate interrow weeding. Wild rice germinating mainly between seeded rows could then be more easily weeded out. About 40% of the total farmers in the area could be interested in this new RLR establishment technique. They belong to farm types II and III, in which RLR is the major activity and where farmers are interested in increasing their net benefits through improved labor productivity. Most of the time, these farmers own a hand-tractor or can easily hire one in the village.

The use of the seeder is not compatible with late tillage of very wet soil and requires more than one plowing on heavy soils to obtain a seedbed with suitable clod sizes for good rice seed distribution. A finer seedbed was obtained by the hand-tractor pulling the row-seeder as the caged wheels helped produce smaller clods in the soil bands where seeds were deposited. Table 5 shows the relationship between seedbed type at sowing and RLR density at emergence. The rate of RLR emergence was higher and more stable in RS (70–100% emergence, with 30–80 seeds distributed m^{-2} depending on seeder spouts as some broken seeds were found) than in BC (10–70% emergence on bigger clods). Potentially, the seeder allows significant savings in the number of seeds needed to establish the RLR crop since additional seedlings are not needed to maintain plant density in fields affected by early vegetative drought.

The efficient use of the row-seeder implies a soil moisture level at sowing that does not allow the clayey soil to stick to the seed distribution system. Experiments showed that the number of "available days" (i.e., days with suitable soil moisture conditions) usually exceeds the number of "necessary days" (days needed to implement the technique in the whole area where it is planned to be used: 1 d ha^{-1} after two plowings by hand-tractor) until early October only (Fig. 3). This constraint limits the possibility for collective ownership of the seeder by several farmers. No thinning-transplanting was

Table 5. Relationship between type of seedbed structure and rainfed lowland rice plant density at emergence in seven farmers' fields on very clayey soils of Sathing Phra, southern Thailand, 1987-88 wet season.

Item	Seedbed structure						
	Coarse	Medium	Medium	Medium	Fine	Fine[a]	Fine[a]
Plant density m^{-2}	81 a	93 ab	132 b	134 b	186 c	238 d	267 d

[a]There may have been some confusion between cultivated and wild rice seedlings in these two infested fields. Numbers followed by the same letter are not statistically significantly different at 5% according to least significant difference criteria.

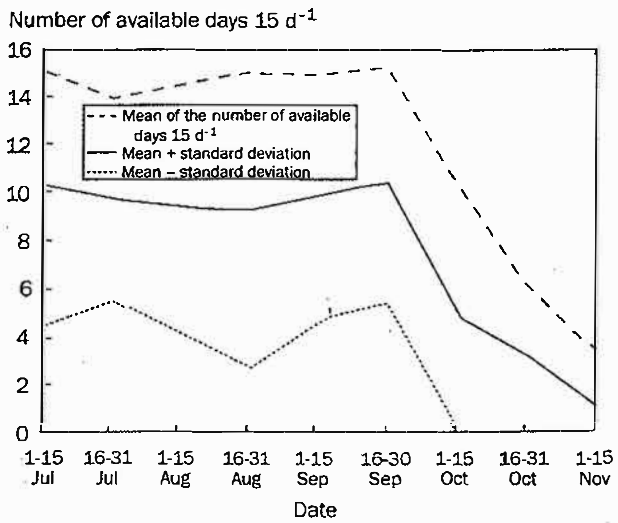

Fig. 3. Analysis of available days for row seeding during 1982-87 in Sathing Phra, southern Thailand.

needed in RS plots in 1987-88 and hand weeding was observed to be twice as long in BC plots than in RS plots with similar weed infestations. This observation was confirmed during similar on-farm experiments carried out the next year in neighboring Phatthalung Province.

Table 6 shows the results of the partial budget analysis for the six collaborative farmers who took part in the row-seeder experiment in the 1987-88 WS. Varying agronomic and economic results were observed in farmers' fields, presenting a gradient in weed infestation. For three farmers' fields with little weed competition, the marginal rate of return (MRR) was negative because in this situation row seeding was a "dominated" treatment (i.e., having a lower net benefit and higher costs that vary). For farmer 3, an MRR of 11% can be considered very low compared with the local cost of investment capital, which can be as high as 120% per year. The very high MRR observed for farmer 2 was due to an exceptionally high RLR yield. Farmer 1 corresponds to a situation in which weed competition was severe, forcing the family to spend 200 and 88 person-d ha^{-1} for hand weeding in broadcast and row-seeded plots, respectively. In this situation, the positive effect of the row-seeder on weeding time and labor productivity is highlighted. The use of the seeder resulted in a 20% increase in labor productivity.

Based on experimental results, the demand for the row-seeder under favorable cropping situations was assessed. For the seeder to be an economically attractive option that decreases varying costs and provides higher labor productivity, a farmer sowing a maximum of 1.6 ha of RLR using this machine usually has to spend more than 38 person-d ha^{-1} in hand weeding and 50 d ha^{-1} for 0.8 ha only. The need for the row-seeder under favorable situations could be estimated by looking at weeding-time data collected in many fields over 2 years (Table 3). Two-thirds (in 1982-83 WS) and 85% (in 1984-85 WS) of the fields showed an advantage in using the row-seeder if it could be used to establish 1.6 ha of RLR per farm, and between half (in 1982-83 WS) and more than two-thirds (in 1984-85 WS) of fields could be considered as having favorable situations if only 0.8 ha of RLR per farm were to be row-seeded. This shows that the row-seeder is potentially an appropriate technique for farm types II and III facing acute weed infestations in their RLR fields as it can significantly help achieve economic objectives by increasing both net benefit per land unit and family labor productivity in a majority of field situations.

Nevertheless, many obstacles to the adoption of this technology remain in the Sathing Phra area because of climatic conditions and the need to use the seeder before early October. This is becoming more and more difficult as farmers are adopting early maturing varieties for planting in September-October. This obstacle to adoption can be even more important for farmers depending on contractors for land preparation and row seeding. Poor water control in RLR also results in plant losses from submergence, which are difficult to forecast. This limits interest in the seeder for establishing a target RLR stand at emergence. The spread of the seeder is also limited because of its heavy weight, leading to difficulties in moving it across bunds. Across the lagoon, in Phatthalung Province, where similar trials were conducted during the 1988-89 WS, mainly RLR growers rearing many cattle became interested in the seeder because the

Table 6. Partial budget analysis comparing rainfed lowland rice broadcasting (BC) and row seeding (RS) on six farms in Sathing Phra, southern Thailand, 1987-88 wet season.

Farmer	1		2		3		4		5		6		Pooled data	
Treatment	BC	RS	BC	RS	BC	RS	BC	RS	BC	RS	BC	RS	BC	RS
Yield (t ha⁻¹)	2.2	2.0	3.4	4.7	1.9	2.3	2.6	2.6	1.9	1.2	3.3	2.3	2.6	2.5
Net yield (t ha⁻¹)[a]	2.0	1.8	2.9	4.0	1.7	2.0	2.3	2.4	1.8	1.1	3.0	2.1	2.3	2.2
Gross benefit (US$ ha⁻¹)	206	185	398	548	206	244	151	153	163	101	356	249	246	246
Costs	146	99	38	64	21	55	101	115	73	91	10	26	65	75
Land preparation	–	–	–	–	–	–	24	26	–	–	–	–	4	5
Seeds	4	3	8	6	9	8	–	–	10	6	4	1	6	4
Sowing	1	10	0.3	18	2	22	0.3	16	1	14	0.5	18	1	16
Hand weeding	80	35	30	40	10	25	30	10	12	24	5	7	28	24
Fertilizers	61	51	–	–	–	–	47	63	50	47	–	–	26	26
Net benefit[b]	60	86	360	484	185	189	50	38 D	90	10 D	346	223 D	181	171 D
Marginal rate of return (%)[c]	Neg.		471		11			Neg.	Neg.		Neg.		Neg.	

[a]Net yield = gross yield – losses (at harvest, storage). [b]Net benefit = gross field benefit – total costs that vary. [c]Marginal rate of return = increment in net benefit divided by increment in costs that vary. D = dominated treatment (lower net benefit and higher costs that vary). Neg. = negative.

twice as fast "weeding" time in row-seeded plots allowed them to rapidly collect enough grass to feed their animals during the wet season. This observation emphasizes the need for a whole-farm systems approach when evaluating the suitability of innovations among different smallholders.

Pattern of changes in crop establishment practices and key research issues

Recent changes in RLR crop establishment practices in this area could be seen as a farmers' response to a key constraint, the decrease in availability of farm labor because of more off-farm employment opportunities during the decade of rapid growth (1986-96), and to a new opportunity to improve water control in medium paddies. For the past 10 years, many farms (up to 50% in some villages) have established a 0.2–0.5-ha plot managed under the so-called integrated farming system. This system is based on a pond surrounded by levees where vegetables and fruit are grown. Apart from fish rearing, water from the pond can be used to provide some supplementary irrigation to neighboring RLR paddies. Several canals have also been dug along the drainage channel; thus, water can be pumped into paddy fields when needed. Farmers would like to increase the network of small secondary canals to allow more paddy fields to have access to supplementary irrigation from these canals. At the same time, the submergence-prone lower paddies, where no improvement in water control occurred, tend to be abandoned or are converted into integrated-farming-systems plots.

The more extensive adoption of early maturing recommended cultivars has recently led to the postponement of sowing dates and this facilitates wet seeding in September-October, especially in paddy fields located along the canals providing supplementary irrigation water. WSR is now increasingly used for RLR establishment. WSR was grown on 50% of the total RLR area during the 1999-2000 crop year, up from only 5% in the early 1980s. In the 1999-2000 WS, DSR and TPR were practiced on 40% and 10% of the remaining RLR paddies, respectively, down from 75% and 20% in the early 1980s, respectively. For the past 5 years, this change occurred parallel with the increased adoption of a new set of early maturing (Khao Dok Mali 105, Khao Hom Suphan, and Khao Klong Luang 1; 120 d) and medium-maturing (Khao Chiang, 150 d) recommended varieties, which covered half of the RLR growing area during the 1999-2000 crop year, compared with only 9% planted to similar types of varieties in the early 1980s. Although farmers are interested in their higher yield potentials and long grains that fetch a better market price, they need to grow them under wet-seeding conditions because they are less tolerant of weed competition than local cultivars. WSR is also becoming more popular because, as off-farm employment opportunities are increasing, less labor is available for transplanting or hand weeding in DSR, and the cost of hired labor for such farm work has doubled from US\$1.50 to \$3.00 d^{-1} during the past 15 years.

More attention could now be directed to improving the leveling of paddy fields to enhance WSR establishment. Research on plot leveling also has implications for land preparation, weed (wild rice) control, water savings, and mineral fertilization. Although 40% of the RLR area is still planted to DSR because water control has not yet been improved, the design of adapted time-efficient integrated methods for wild rice control remains the main research priority.

Conclusions

Recent important changes in farmers' crop establishment practices in the Sathing Phra area emphasized the importance of improvements in water control, with other strategies such as diversification of production and other economic activities to help mitigate climatic and economic risks in RLR-based farming systems. If efforts in that direction are sustained, WSR will likely continue to replace DSR and TPR in this more and more favorable RLR growing area in the future.

This case study has also demonstrated the importance of improving labor productivity in RLR as we are dealing with small farmers who are well integrated into the market economy and for whom the opportunity cost of labor is increasing. Consequently, this criterion should be very high on the list of indicators for assessing and evaluating new technologies in RLR production. At the same time, the experience of improving traditional RLR systems in Sathing Phra has highlighted the relevance of the whole-cropping-systems approach and farming systems approach for designing, testing, and evaluating technical innovations, such as crop establishment practices, with farmers.

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